To: Staci Goodwin, TMDL Program Manager, IDEM
From: Rhett Moore, Senior Hydrologist, WHPA Inc.
Date: May 19, 2003
Subject: Salt Creek Watershed and Water Quality Modeling / Analytic Framework

TECHNICAL MEMORANDUM

This memorandum describes WHPA's proposed Modeling Framework for development of an *E. coli* TMDL for Salt Creek in Porter County, Indiana. This memo will discuss the following aspects of the Modeling Framework:

I.Modeling Objectives

II.Model Selection

III.Approach

IV.Stakeholder Input

V.References

I. MODELING OBJECTIVES

The modeling tools utilized for TMDL development must be able to accommodate the following objectives:

1. **Identify cause and effect relationship between *E. coli* sources and observed water quality.**
   Development of an *E. coli* TMDL for Salt Creek requires an understanding of the capacity of the watershed to assimilate loads and the relationship between source loading and observed concentrations in the creek.

2. **Identify loading capacity.**
   After the link has been established, the total capacity of Salt Creek to assimilate *E. coli* loading can be evaluated. Crucial environmental conditions must be considered.

3. **Develop, test, and evaluate potential allocations consisting of Waste Load Allocations, Load Allocations, and a Margin of Safety (MOS).**
   After the prior objectives have been satisfied, the impact of different point and nonpoint source loading scenarios can be predicted. Potential scenarios can be simulated and the load reductions required for attainment can be allocated among the various sources.

4. Evaluate uncertainties.

Establishment of an arbitrary MOS can lead to inadequate or unnecessary load reductions. The relative importance of uncertainties in predicted scenarios can be evaluated in the modeling process to gauge assumptions and resulting effects on loading scenarios. To the extent possible, the MOS will be based on an analysis of uncertainty.

II. MODEL SELCTION

Model Requirements

Selection of the most appropriate analytical tools for fulfillment of the modeling objectives were based on two sets of requirements: 1.) technical requirements dictated by the Salt Creek watershed, the nature of impairment, and the physical characteristics of the contaminant, and 2.) non-technical, ancillary requirements.

Prior to development of a Modeling Framework, existing information from the watershed was compiled, analyzed, and presented in the Salt Creek Data Report. The technical model requirements for TMDL development in Salt Creek were developed based on attributes of the watershed and conclusions in the Data Report. Results from the Data Report that factored into development of model requirements include: 1.) The watershed includes mixed and variable land use; 2.) Both point and nonpoint sources are relevant in the watershed; 3.) *Escherichia coli* concentrations exceeding both standards were found to be geographically extensive; impairment was observed along the entire length of Salt Creek as well as many of the tributaries; 4.) *Escherichia coli.* concentrations exceeding the single-sample standard were associated with episodic, wet weather events.

The technical model requirements dictated by aspects of the Salt Creek watershed and characteristics of the contaminant of concern include:

- Reliable simulation of bacteria loading from point sources, including Combined Sewer Overflows
- Reliable simulation of watershed-scale bacteria loading from nonpoint sources
- Reliable simulation of a watershed with mixed land use
- Reliable simulation of dynamic aspects of flow in Salt Creek, including low flow and storm events
- Reliable simulation of *E. coli* dynamics in the environment, including buildup/washoff, in-stream fate, and transport
- Timeseries output that enables comparison of predicted concentrations with both the single-sample standard and the geometric mean standard

Ancillary model requirements include:

- Model must be robust and scientifically defensible
- Model must be open source, documented, tested, and accepted
- Requirements of model implementation and support must not outweigh available resources

Model Evaluation

The technical model requirements dictate that the model or models used for Salt Creek TMDL development be capable of simulating bacteria loading on a watershed scale, hydrology, in-stream processes, and *E. coli* transport. The model must be able to simulate the above aspects at a time step appropriate for analysis of storm events. WHPA believes that a comprehensive, dynamic simulation model is critical for realistic representation of watershed processes in Salt Creek.

WHPA proposes utilization of BASINS 3.0 for the modeling analysis. Use of the BASINS package will ensure that the ancillary model requirements listed above are fulfilled. BASINS is a collection of tools and data packaged by USEPA specifically for TMDL development. BASINS streamlines the process of data preparation and model application in watershed studies, greatly simplifying the implementation and support of detailed models. The current version includes two comprehensive, dynamic models capable of the continuous simulation of loading and in-stream processes warranted by the technical modeling requirements: the Source Water Assessment Tool (SWAT) and the Hydrologic Simulation Program-Fortran (HSPF).

SWAT

WHPA first evaluated the potential for SWAT 2000 to satisfy the modeling objectives. SWAT was an attractive option for three reasons: 1.) SWAT 2000 has newly incorporated bacteria transport routines; 2.) SWAT is less resource intensive than HSPF; for example,preparation of input files for SWAT are less time consuming; 3.) WHPA modeling staff has a relationship with the author of the code and researchers at Baylor University that would have facilitated direct support from expert users.

WHPA learned from our evaluation of SWAT 2000 that the efficacy of the bacteria routines is not adequate enough to satisfy the modeling objectives. The bacteria routines,implemented for the first time in SWAT 2000, have not been tested. Mr. David Wells, a SWAT expert with the USEPA BASINS staff, stated that “although it appears to be set up to model bacteria, it can not yet” (Wells, 2003). In addition, assuming that the bacteria routines were functional as advertised, SWAT 2000 could only simulate bacteria inputs as constant loads. This means that even if the new routines were proven to be robust, SWAT 2000 provides no way to properly simulate the temporal aspects of source loading described in the modeling requirements.

HSPF

WHPA proposes that HSPF is the best choice for development of an *E. coli* TMDL for Salt Creek. The model, as packaged with BASINS 3.0, is very suitable for fulfilling the model requirements defined above. HSPF is a comprehensive watershed model capable of simulating point and nonpoint source runoff and pollutant loading for a watershed. In addition, the model can simulate flow and water quality routing in stream reaches (USEPA, 2001; Bicknel and others, 2001). HSPF can be accessed in BASINS 3.0 through an interface called *Win*HSPF (Duda and others, 2001). Earlier versions of the interface were known as the Nonpoint Source Model. *Win*HSPF was developed to ease the complexity of building and modifying input files for HSPF. The interface also enhances the modeler's ability to understand and represent model output.

The technical and ancillary requirements used for model selection are presented above. The technical requirements were based on characteristics of *E. coli* and unique aspects of impairment in the watershed. HSPF is capable of satisfying the technical requirements for the following reasons:

- HSPF can reliably simulate flow in a gauged watershed.
- HSPF can simulate runoff in a mixed land use setting like Salt Creek.
- HSPF can simulate bacteria loading from point sources.
- HSPF has the capability to simulate the temporal aspects of buildup and washoff from nonpoint sources.
- HSPF can simulate the in-stream fate and transport of bacteria.
- HSPF can simulate flow and contaminant dynamics in a timestep small enough to allow inclusion of storm events.
- Output from HSPF allows comparison of predicted concentrations with both the single-sample standard and the geometric mean standard.

HSPF satisfies the ancillary model requirements above for the following reasons:

- HSPF has a proven track record for bacteria modeling; the code has been utilized for development of fecal coliform TMDLs across the country.
- HSPF is open source, established and accepted in the field, well documented, and well supported by USEPA.
- USEPA recommends HSPF as the most accurate and appropriate management tool available for the continuous simulation of hydrology and water quality in watersheds (Hydrocomp, 2003).
- David Wells of USEPA BASINS Staff confirmed our evaluation. Mr. Wells concurred that HSPF is the superior code for modeling bacteria at the present time (Wells, 2003).
- The Windows interface, combined with the pre- and post-processing functions of BASINS, greatly reduces the resources required for implementation of a detailed watershed model.

III. MODELING APPROACH

Load Estimation

HSPF also complements our utilization of the Bacterial Indicator Tool for the Source Assessment. The Bacterial Indicator Tool, also distributed with BASINS 3.0, is a spreadsheet that estimates the bacteria contribution from multiple sources (USEPA, 2000). The spreadsheet was produced for use with fecal coliform, but was developed with adaptation in mind. WHPA adapted the spreadsheet for use with *E. coli* by modifying production parameters. The worksheets estimate the loading rate from livestock, wildlife, and failing septics. In addition, output sheets estimate the accumulation rate and buildup limit of fecal waste on four different land uses (cropland, forest, built-up, and pastureland). Output from the spreadsheets can easily be used as input to *Win*HSPF and the HSPF watershed loading components.

Input/Output

The input data for HSPF will include the following data sets:

- Land Use/Land Cover (U.S. Geological Survey , 2000)
- Soils (U.S. Dept. of Agriculture, 1994; U.S. Dept. of Agriculture, 2002)
- Elevation (U.S. Geological Survey, 1999)
- Climate (NCDC, 2002)
- Point Sources (WHPA, 2003a; WHPA, 2003b)
- Nonpoint Sources (WHPA, 2003b)

Output from HSPF will include:

- Predicted timeseries for runoff
- Predicted timeseries for pollutant loading

Calibration

Calibration of flow and loading will be based on methods described in Santhi and others (2001), Saleh and others (2000), and Donigian (2002). Calibration of flow will be accomplished by comparing observed and simulated flows and evaluating the comparison based on summary statistics. Flow will be calibrated with the data from the McCool gage described in the Salt Creek Data Report (WHPA, 2003a). Unfortunately, the McCool gage was retired in 1991. However, it is imperative to use data from the watershed to the extent possible. Flow will be calibrated and verified with data from 1985-1991. Loading will be calibrated and verified with the data sets deemed “acceptable” in the Salt Creek Data Report.

Ancillary Tools

Included in the BASINS 3.0 package are various ancillary tools that enhance the analysis process. Ancillary tools that WHPA plan to utilize include WDMUtil and GenSCn. WDMUtil is a utility for managing binary timeseries data sets. The WDM format was developed by the USGS and is used by HSPF for input and output timeseries data. GenSCn is a postprocessor that facilitates the display and interpretation of output data.

WHPA will utilize a baseflow separation program to estimate characteristics of the ground water flow component in the watershed. The program is described in Arnold and others (1995) and Arnold and others (1999). Daily values from the period of record at the McCool gage will be used as input. The estimated ground water contribution will be used to calibrate the flow model.

IV. STAKEHOLDER INPUT

The Modeling Framework for Salt Creek TMDL development will be presented to the public for comment upon approval by the State. This document will be made available on-line at the State's website and at the WHPA project website (www.saltcreektmdl.org). WHPA will also work with the State to present the Modeling Framework and results from the Source Assessment at a stakeholder meeting in the watershed. Comments will be compiled and considered with the State for incorporation into the reports or subsequent phases of the project.

V. REFERENCES

Arnold, J., Allen, P., Muttiah, R., Bernhardt, G., 1995, Automated base flow separation and recession analysis techniques, Ground Water 33(6):1010-1018.

Arnold, J., Allen, P., 1999, Automated methods for estimating baseflow and ground water recharge from streamflow records, Journal of the American Water Resources Association 35(2):411-424.

Bicknell, B., Imhoff, J., Kittle, J., Jobes, T., Donigan, A., 2001, Hydrologic Simulation Program-Fortran, Version 12, Aqua Terra Consultants, U.S. Environmental Protection Agency, Contract No. 68-C-98-010.

Donigan, A. S., 2002, Watershed Model Calibration and Validation: The HSPF Experience, Aqua Terra Consultants, Proceedings of TMDL Sciences Issues Conference, Pheonix, November 2002, Water Environment Federation.

Duda, P., Kittle, J., Gray, M.,Hummel, P., and Dusenbury, R., 2001, WinHSPF User's Manual, Aqua Terra Consultants, U.S. Environmental Protection Agency, Contract No. 68-C-98-010.

Hydrocomp, 2003, Hydrologic Simulation Program-Fortran, http://www.hydrocomp.com/HSPFinfo.htm. Accessed on February 16, 2003.

NCDC, 2002, Cooperative Summary of the Day, TD3200, National Climate Data Center. CD-ROM.

Saleh, A., Arnold, J., Gassman, P., Hauck, L., Rosenthal, W., Williams, J.,McFarland, A., 2000, Application of SWAT for the Upper North Bosque River watershed, Transactions of the American Society of Agricultural Engineers 43(5): 1077-1087.

Santhi, C., Arnold, J., Williams, J., Dugas, W., Srinivasan, R., Hauck, L., 2001, Validation of the SWAT model on a large river basin with point and nonpoint sources, Journal of the American Water Resources Association 37(5):1169-1188.

U.S. Department of Agriculture, 1994, State soil geographic (STATSGO) database for Indiana, Natural Resources Conservation Service, Fort Worth, Texas.

U.S. Department of Agriculture, 2002, Downloaded from the Official Soil Series Descriptions website, http://www.ortho.ftw.nrcs.usda.gov/osd/. USDA Soil Survey Division, Accessed September 30, 2002.

U.S. Environmental Protection Agency, 2000, Bacterial Indicator Tool User's Guide, Office Of Water, EPA-823-B-01-003.

U.S. Environmental Protection Agency, 2001, Better Assessment Science Integrating Point and Nonpoint Sources, Version 3.0, Office of Water, EPA-823-B-01-001.

U.S. Geological Survey, 1999. downloaded from the National Elevation Data Set website, http://www.edcnts12.cr.usgs.gov/ned/, EROS Data Center.

U.S. Geological Survey, 2000. Downloaded from the Indiana Land Cover Dataset, edition 1 website. http://edcwww.cr.usgs.gove/programs/lccp/nationallandcover.html.

Wells, D., 2003, Written communication, January 30, 2003. U.S. Environmental Protection Agency, BASINS Support Team.

WHPA, 2003a, Salt Creek *E. coli* TMDL Data Report, Technical Report, Wittman Hydro Planning Associates, Unpublished data.

WHPA, 2003b, Salt Creek *E. coli* TMDL Source Identification and Assessment Report, Technical report, Wittman Hydro Planning Associates, Unpublished data.